Tuijin Jishu/Journal of Propulsion Technology
ISSN: 1001-4055
Vol. 45 No. 4 (2024)

Flexural Properties, Wear Resistance, and Microstructural Analysis of Highly Filled Flowable Resin Composites and Packable Composites

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***Abstract:*- Background:** This study was conducted to assess the flexural properties, wear resistance, and for microstructural analysis of highly filled flowable resin composites and packable composites.

Material and methods: For each group of resin composites (n=10), a total of 10 specimen bars were produced utilizing a silicon mold to facilitate the assessment of flexural strength (FS), flexural modulus (E), flexural toughness (FT), Weibull modulus (m), and scanning electron microscopy (SEM) microstructural analysis. Within each group, 8 bars underwent testing via a three-point flexural test on a universal testing machine, while the remaining 2 bars were embedded in acrylic resin for subsequent SEM examination to analyze their structural characteristics. In the two-body wear test conducted with a chewing simulator, 6 specimens from each resin composite group were created using a designated mold and subjected to 120,000 wear cycles against a steatite ball, with the depth of material loss being recorded. To evaluate the differences in flexural and wear properties across the various groups, three one-way ANOVA tests were performed, followed by Tukey's post hoc tests.

Results: In this study, the mean flexural strength of packable composites (128.26±47.6 Mpa) was higher than that of flowable composites (106.56±89.5 Mpa). The flexural modulus of flowable composites (4.63 Gpa) was lower than that of packable composites (11.65 Gpa). It was observed that flowable composites showed 20.3 µm wear while the packable composites showed 9.7 µm wear, indicating that packable composites have better wear resistance as compared to flowable composites.

Conclusion: From the results of this study, it can be concluded that packable composites have superior wear resistance, flexural modulus and flexural strength as compared to highly filled flowable composites. Even though the filler content is high in flowable composites, packable composites are still better than flowable composites and can also be used for posterior restorations.

Keywords*: wear resistance, flowable composites, resin.*

1. Introduction

The use of resin-based composite dental materials (RBC) has increased worldwide, because of rising demand for cosmetic, tooth-colored, and mercury-free restorations.[1] Light-cured resin-based dental composite restorative materials are typically used in compound and complex cavities.[2,3]

However, the limited depth of cure of these materials necessitates using multiple incremental layers when placing them in such cavities.[4,5] Incremental application decreases the shrinkage stress while increasing the time and number of curing cycles required to complete the restoration.[6] As a result, there is a rise in demand from clinicians for RBCs to be provided which use simpler and faster processes.

One of the most important factors that influences the physical and mechanical properties of composites is the degree of conversion. A lower degree of conversion results in restorations with lower mechanical properties, color changes, and greater degradation.[7] There are several techniques for evaluating the polymerization of composites, which can be divided into two main groups: direct and indirect methods.

Direct methods, such as Fourier Transform Infrared Spectroscopy (FTIR), are expensive, complex, and time-consuming. In FTIR spectroscopy, the absorption of infrared radiation by the double bond of carbon is evaluated before and after curing, based on an accurate formula. In contrast, indirect methods, such as hardness and scraping tests, are inexpensive and easy to perform. Surface hardness is defined as the penetration of an indenter into the material[8]

This study was conducted to assess the flexural properties, wear resistance, and for microstructural analysis of highly filled flowable resin composites and packable composites.

2. Material and Methods

For each group of resin composites (n=10), a total of 10 specimen bars produced utilizing a silicon mold to facilitate the assessment of flexural strength (FS), flexural modulus (E), flexural toughness (FT), Weibull modulus (m), and scanning electron microscopy (SEM) microstructural analysis. Within each group, 8 bars underwent testing via a three-point flexural test on a universal testing machine, while the remaining 2 bars were embedded in acrylic resin for subsequent SEM examination to analyze their structural characteristics. In the two-body wear test conducted with a chewing simulator, 6 specimens from each resin composite group were created using a designated mold and subjected to 120,000 wear cycles against a steatite ball, with the depth of material loss being recorded. To evaluate the differences in flexural and wear properties across the various groups, three one-way ANOVA tests were performed, followed by Tukey's post hoc tests.

3. Results

Table 1: Flexural strengths of flowable and packable composites

Type of composite	Mean flexural strength (Mpa)
Flowable	106.56±89.5
Packable	128.26±47.6

The mean flexural strength of packable composites (128.26±47.6 Mpa) was higher than that of flowable composites (106.56±89.5 Mpa).

Table 2: Flexural moduli of flowable and packable composites

Type of composite	Flexural modulus (Gpa)
Flowable	4.63
Packable	11.65

The flexural modulus of flowable composites (4.63 Gpa) was lower than that of packable composites (11.65 Gpa).

Table 3: Wear resistance of flowable and packable composites

Type of composite	Wear of composite (µm)
Flowable	20.3
Packable	9.7

It was observed that flowable composites showed 20.3 µm wear while the packable composites showed 9.7 µm wear, indicating that packable composites have better wear resistance as compared to flowable composites.

4. Discussion

The use of resin-based materials is gaining popularity in dental practice due to ease of application, excellent esthetic outcomes, adequate mechanical properties, and adaptability.[9,10] However, there are still a room for further modification of RBC due to some inherent drawbacks in these materials such as technique sensitivity, polymerization shrinkage which can lead to gap formation and microleakage, time needed for incremental application, low wear and abrasion resistance and marginal deterioration.[10]

Flexural strength is a critical parameter used to assess the structural reliability of composite materials and their ability to withstand occlusal loads without fracturing. In addition to that, the flexural test also provides the elastic modulus of the material, which is a measure of the material's rigidity and its ability to withstand occlusal forces without experiencing significant elastic deformation[11], therefore, flexure strength and elastic modulus were conducted in the present study to evaluate the mechanical behavior of the tested materials. Flexure strength and elastic modulus are influenced by several factors in composite materials, including type of resin matrix, degree of crosslinking and polymerization, in addition to type, size and amount of filler loading.[12,13]

This study was conducted to assess the flexural properties, wear resistance, and for microstructural analysis of highly filled flowable resin composites and packable composites.

In this study, the mean flexural strength of packable composites (128.26±47.6 Mpa) was higher than that of flowable composites (106.56±89.5 Mpa). The flexural modulus of flowable composites (4.63 Gpa) was lower than that of packable composites (11.65 Gpa). It was observed that flowable composites showed 20.3 µm wear while the packable composites showed 9.7 µm wear, indicating that packable composites have better wear resistance as compared to flowable composites.

Asefi S et al (2016)[14] in their study compared wear resistance of two flowable composite resins with that of posterior composite resin materials. Thirty-five disk-shaped specimens were prepared in 5 groups, including two flowable composite resins (Estelite Flow Quick and Estelite Flow Quick High Flow), Filtek P90 and Filtek P60 and Tetric N-Ceram. The disk-shaped samples were prepared in 25-mm diameter by packing them into a two-piece aluminium mold and then light-cured. All the specimens were polished for 1minute using 600-grit sand paper. The samples were stored in distilled water at room temperature for 1 week and then worn by two-body abrasion test using "pin-on-disk" method (with distilled water under a 15-Nload at 0.05 m/s, for a distance of 100 meter with Steatite ceramic balls antagonists). A Profilometer was used for evaluating the surface wear. Data were analysed with the one-way ANOVA. Estelite Flow Quick exhibited 2708.9 ± 578.1 µm (2) and Estelite Flow Quick High Flow exhibited 3206 ± 2445.1 µm (2) of wear but there were no significant differences between the groups. They demonstrated similar wear properties. Estelite flowable composite resins have wear resistance similar to nano- and micro-filled and micro-hybrid composite resins. Therefore, they can be recommended as pit and fissure sealant materials in the posterior region with appropriate mechanical characteristics.

Turk S et al (2024)[15] in their study assessed the wear resistance of conventional and flowable composites containing different filler types using thermomechanical chewing simulation. Six different composite resin materials were used: a conventional and flowable composite from each of three manufacturers respectively classified by different filler characterizations: (1), a nanohybrid conventional (G-aenial Posterior, GC) and flowable (G-aenial Universal Injectable, GC), (2) a nanofilled conventional (Filtek One Bulk-fill Restorative, 3M) and flowable (Filtek Ultimate Flow, 3M), and submicron-filled conventional (Estelite Posterior Quick, Tokuyama) and flowable (Estelite Bulk-Fill Flow, Tokuyama). The buccal surfaces of extracted human premolars were planarly abraded and used as control (n = 12). The prepared surfaces were subjected to wear using a thermocycler chewing simulator against 6-mm diameter steatite balls for 240,000 cycles, simulating 1 year of in vivo use. Digital profiles of treated sample surfaces were scanned using a laser scanner, and the volume loss and maximum depth of loss were calculated. Two-way MANOVA was used to compare the wear volume loss and depth according viscosity (conventional/flowable) and filler type (nanohybrid, nanofilled, submicron-filled), and multiple comparisons were performed using Duncan's test. Wear volume loss and loss depth were significantly lower in enamel than in all composite resin groups. The wear volume loss and loss depth of nanofilled composites were significantly higher than the other composite filler types, with no significant difference in either parameter between the nanohybrid and submicron-filled composite groups. With respect to apparent viscosity, wear volume loss and loss depth of conventional composites were significantly lower than the flowable composites. The type of composite filler and its apparent viscosity significantly influence the in vitro wear resistance of the material. All composite materials tested demonstrated a susceptibility to simulated wear that was two to three times greater than that of human enamel.

Francois P et al (2024)[16] conducted a study that aimed to evaluate the flexural properties and two-body wear resistance of nine highly filled flowable resin composites relative to those of viscous and conventional low-filled flowable composites. In addition, scanning electron microscopy (SEM) analysis of the microstructures was performed. For each resin composite group (n=12), 12 specimen bars (25 mm × 2 mm × 2 mm) were fabricated using a silicon mold for performing flexural strength (FS), flexural modulus (E), flexural toughness (FT), Weibull modulus (m) tests, and SEM microstructural analysis. For each group, ten bars were tested using a three-point flexural test on a universal testing machine, while the other two were embedded in acrylic resin before being observed by SEM for structural analysis. During the two-body wear test with a chewing simulator, 8 specimens (12 groups, n=8) of each resin composite group were manufactured in a specific mold and subjected to 120,000 cycles of wear against a steatite ball, and the depth loss was measured. Three one-way ANOVA tests followed by Tukey's post hoc tests were conducted to compare the flexural and wear properties among the different groups. The majority of highly filled composites tested in this study exhibited similar flexural strengths (between 105.68 MPa and 135.49 MPa) and superior wear resistance to those of viscous composites. The flexural moduli (between 5.12 GPa and 9.62 GPa) of these composites were in between those of the viscous and low-filled composites tested in this study. The highly filled flowable composites tested in this study exhibited different in vitro properties but were often superior to those of viscous resin composite suggesting their possible use for posterior restorations.

5. Conclusion

From the results of this study, it can be concluded that packable composites have superior wear resistance, flexural modulus and flexural strength as compared to highly filled flowable composites. Even though the filler content is high in flowable composites, packable composites are still better than flowable composites and can also be used for posterior restorations.

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